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(54) METAL SEALS

(71) We, MONSANTO COMPANY, a corporation organised under the laws of the State of Delaware, United States of America, of 800 North Lindbergh Boulevard, St. Louis 66, State of Missouri, United States of America do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates generally to a metallic seal, and more particularly to a self-sealing, metal seal for use with a control valve or the like, the temperature cycling of which results in substantial thermal expansion and constraction of its constituent parts.

Heretofore, it has been the general practice to employ flat, disk-like seals between various mating parts of fluid carrying apparatus, such as pipe couplers, control valves, and the like. Some such seals have not proven satisfactory where the mating parts have substantially different coefficients of thermal expansion and are used in applications where extreme temperature cycling takes place. For example, control valves used to control the flow of steam in a pipeline are often comprised of a valve body together with an internal cage member which is fitted within the valve body to form a valve seat and a guide for the travel of a reciprocating valve plug. Oftentime, the valve body and the cage member have different coefficients of thermal expansion, such that temperature cycling of the valve via that of the fluid therethrough, results in expansion or contraction of the fitted-together members. The expansion and contraction may result in unacceptable loosening of the seal between the cage member and valve body or in the crushing of the seal, depending on whether the valve body and member expand away from or toward each other, respectively. Either result may lead to fluid leakage.

Annular expandable metal seals having C, U or V-shaped cross-sections are available and well known. These seals generally have a cross-section which is of a uniform or constant thickness throughout, or where the flange portions have a cross-sectional thickness which is substantially less than that of the portion which joins them together. Although these seals are capable of substaining substantial loads, they do not exhibit the necessary spring-action or deflection and recovery characteristics suitable for a seal which must carry a substantial load and at the same time exhibit sufficient deflection characteristics to deflect and recover a substantial amount to maintain a leakproof seal under temperature cycling conditions.

According to the present invention there is provided a metal seal, comprising a continuous, one-piece, annular, generally C,V or U-sectioned body of resilient metal having a pair of radially-directed flange portions joined by an integral hinge portion, the ratio of the thickness of the hinge portion to that of any part of flange portions being such that when the flange portions are loaded axially of the annular body toward one another the elastic limit of the hinge portion is less than that of any part of the flange portions.

According to a further aspect of the present invention there is provided a control valve fitted with a metal seal of the invention as defined above.

According to a yet further aspect of the present invention there is provided a control valve and metal seal, combination, comprising a valve body including inlet and outlet ports, a valve cage member having a coefficient of expansion differing from that of the valve body positioned within the valve body between the inlet and outlet

ports, the valve cage member being secured to the valve body in such a manner to define a seal cavity between the cage member and the valve body, the cage member defining a valve seat, a valve plug mounted within the valve cage member for reciprocal movement toward and away from the valve seat, a metal seal comprising a continuous one-piece, annular, generally C, V or U-section body of resilient metal secured within the seal cavity, the metal seal having a pair of radially directed flange portions coupled together by an integral hinge portion, the ratio of the thickness of the hinge portion to that of any part of the flange portions being such that when flange portions are loaded axially of the annular body towards one another, the elastic limit of the hinge portion is less than that of any part of the flange portions, whereby the metal seal exhibits sufficient resilient deflection and load-carrying characteristics to maintain a leak-tight seal notwithstanding thermal contractions or expansions of the seal cavity.

In some cases such action can be achieved where such ratio is less than one. Employing such resign characteristics, the seal is capable of providing a leakproof seal notwithstanding substantial temperature cycling of the mating parts between which it is confined.

In general this provides a self-sealing, metallic seal which can be fitted into a narrow,confined space, and yet have substantial load-carrying and elastic deflection characteristics similar to a spring.

Moreover, the self-sealing, metal seal can often be employed between closely-fitted mating parts of a control valve to provide an effective leakproof seal under expansion and contraction conditions.

The metal seal has portions which have either plastic deformation or resilient deflection characteristics, the combination of such portions providing a compact seal for carrying quite large loads and, in addition, providing substantial deflection and recovery characteristics.

The metal seal preferably comprises a continuous one-piece annular body of stiff resilient metal.

FIGS, 1*a* and 1*b* are cross-sectional views of typical prior art annular, metallic seals;

FIG, 2 is a perspective view of a preferred embodiment of the seal of the present invention useful in applications where internal seal pressure aids the sealing action thereof;

FIG. 3 is a cross-section view of the spring seal of FIG. 2; and

FIG. 4 is a cross-sectional view of an alternative embodiment of the seal of the present invention also useful in applications where internal seal pressure aids its sealing action;

FIGS. 5 and 6 are cross-sectional views of seals similar in their general configuration to those of FIGS. 3 and 4, respectively but wherein external seal pressure is employed to aid the sealing action thereof;

FIGS. 7 and 8 are cross-sectional views of a control valve fitted with a metal seal of the present invention to seal between mating parts thereof, FIG. 8 being an enlarged, partial cross-section of the seals and valve as shown in FIG. 7, and

FIG. 9 is a graphical representation of the typical deflection vs. load characteristic of a spring seal of the present invention.

Referring now to FIGS. 1*a* and 1*b*, there are shown two typical prior art metal seals generally designated *a* and *b*, respectively. The metal seal *a* is generally annular in overall shape and has a V-shaped cross-section, whereas the metal seal *b* is generally C-shaped in cross-section. It should be noted that the flange portions *c* and *d* of the metal seal *a* have a thickness which is substantially less than the thickness of the hinge *e* which connects these leg portions. The metal seal *b* has flange portions *f* and *g* which similarly have thicknesses, each substantially equal to that of the hinge *h* by which they are joined.

It has been found that in loading either of the metal seals *a* or *b*, substantially all of the deflection is taken by the flange portions *c*, *d* and *f*, *g*, respectively, and that there is little or no deflection afforded by the hinges *e* and *h* which connect these flange portions. As a result, these metal seals are limited in their application and do not prove to be satisfactory for applications where a significant deflection and recovery of the seal is important to its overall operation.

Referring now to FIGS. 2 and 3, there is shown a metal seal, generally designated 10, constructed in accordance with the present invention. The metal seal 10 is annular in its overall configuration and has a generally U-shaped cross-section. It is comprised of upper and lower plastically deformable, flange portions 12 and 14, respectively, joined together and spaced-apart from each other by an integrally formed, substantially resiliently deflectable, coupling or hinge portion 16 along its outer periphery. In this manner of construction, the seal 10 is provided with an internal-groove or opening 17 which is useful in applying pressure to spread the flange portions 12 and 14, thereby aiding in the sealing action. Preferably, the seal is formed from a metal having resilient, spring characteristics such as the metal alloy, commercially known as Inconel 718, (Inconel is a registered trade mark) having

high yield strength at extreme temperatures, say 1000° F to 1200° F. It should be noted that the flange portions 12 and 14 of the metal seal 10 are relatively thick in comparison to the cross-section hinge portion 16 so that, in use, the deformation of the hinge portion 16 is substantially plastic deformation (i.e. above the metal yield stress) while the deformation of the flange portions 12 and 14 is resilient deflection (i.e. less than the metal yield stress). We have found that for many metals and alloys it is necessary to design the metal seal 10 such that the ratio of the thickness of the flange portions 12 and 14 to that of the thickness of the hinge portion 16 is at least greater than one (1) to achieve the desired results. Preferably, for Inconel 718, we have found that the thickness of each of the flange portions 12 and 14 should be about eight (8) times greater than the thickness of the hinge portion 16 of the metal seal 10 to obtain this result. In this manner, the seal 10 acquires spring-like characteristics which allows it to deflect and recover substantially, yet at the same time carry loads large enogh to assure an effective seal. For example, a metal seal made in accordance with our invention having an overall thickness of about 3/4 inch, an outside diameter of about five inches, an inside diameter of about 3.5 inches, flange portions of about 1/4 inch thickness, and a hinge portion of about 1/32 inch thickness, exhibited a load-deflection characteristic as illustrated in FIG. 8, wherein, after the initial loading, the seal deflected over a range of approximately 0.100 inch while sustaining a load of from 0 to 14,000 lbs.

It has been found that when the ratio of the thickness of the flange portions 12 and 14 to that of the hinge portion 16 is about 8 to 1, then the metal seal 10 takes on the desirable deflection and load-carrying characteristics because the hinge portion 16, rather than being a static member as in the case of the hinge portions for prior art metal seals, become a dynamic, plastic-like hinge. That is, the hinge 16 deflects in its plastic-stress region when the metal seal 10 is loaded and shares a portion of the load with the flange portions 12 and 14. Thus, the metal seal 10 has the characteristic that it is capable of carrying substantial forces in its flange portions 12 and 14, yet at the same time is able to undergo the combination of plastic deformation (due to hinge portion 16) and spring-like resilient deflection (due to flange portion 16). These characteristics and the advantages which are derived therefrom will become apparent from the description of the use of the metal seal ten mating parts of a control valve, to be described hereinafter.

The metal seal 10 is provided with annular lips 19 and 21 which protrude outwardly from the surface of the upper and lower load-carrying portions 12 and 14, respectively. These annular lips 19 and 21 serve to concentrate the sealing pressures which are applied to the surface of the parts to be sealed.

In FIG. 4 there is shown an alternative seal 10′ designed in accordance with the present invention. Instead of having a U-shaped cross-section, the spring seal 10′ has a V-shaped cross-section. It should be noted, however, that in accordance with the present invention the hinge portion 16′ of the seal 10′ has a cross-sectional thickness which is much less than that of either of the flange portions 12′ and 14′.

In FIGS. 5 and 6, metal seals similar to those of FIGS. 3 and 4 are shown. However, the seals 10″ and 10‴ of FIG. 5 and 6 have their hinge portions 16″ and 16‴ positioned along the inner diameter of the seal and their annular sealing lips 19″ and 19‴ and 21″, 21‴ formed along the outer diameter of the seal. In this manner, the grooves 17″, 17‴ open outwardly so that external pressures applied to the seals 10″ and 10‴, cause the flange portions 12″, 12‴ and 14″, 14‴ to spread apart to effect an enhanced seal between the annular lips 19″, 21″, 19‴, 21‴ and the parts to be sealed.

Referring now to FIGS. 7 and 8, there is shown, in partial cross-section, a portion of a control valve including a bonnet member 18 secuered to a valve body 20 by means of bolts 22. Between the bonnet member 18 and the valve body 20, there is provided a cage member 24, the lower portion 26 of which is provided with an annular valve seat 28 which is positioned between the control valve inlet 30 and outlet 32. The cage member 22 is generally cylindrical in shape and includes flow passage windows 40 and 41. Reciprocally mounted within the cage member 24 for movement relative to the windows 40 and 41, is a cylindrical valve plug 34 having its upper end secured to a valve stem 36 by means of a fastening pin 38. As is well known, the valve stem 36 may be connected to an appropriate actuator (not shown). The valve plug 34 is designed to seat against the valve seat 28, in the closed position. Movement of the valve plug 34 away from this closed position meters the flow of fluid past the valve seat 28, through the windows 40, 41 of the cage member 24, to the valve outlet 32.

In a cavity 42 defined by the lower portion 26 of the cage 24 and a slot or groove 25 provided in the valve body 20, there is provided a metal seal 10 formed in accordance with the present invention. As shown,

the metal seal 10 is deflected in its normal position with its sealing lips 19, 21 mating against the lower portion 26 of the cage member 24 and the valve body 20, respectively, to provide an effective seal. It should be noted that the metal seal 10 is positioned in the cavity 42 such that high pressure from the valve inlet 30 tends to expand the seal 10 to urge its sealing lips tightly against the surfaces to be sealed.

In operation, where the valve body 20 and cage member 24 are subjected to temperature cycling, the cage member and valve body may first expand upon temperature increase, thereby applying a compression force to the metal seal 10 such that its flange portions 12 and 14 and hinge portions 16 are deflected. The metal seal 10 of the present invention allows such deflection to take place readily because hinge portion 16 is sufficiently thin in comparison to the much thicker flange portions to undergo plastic deformation. As temperature cycling proceeds and the temperature decreases, the cage member 24 and the valve body 20 contract, usually at different rates, and thereby enlarge the cavity 42. The metal seal 10 recovers and follows such contraction readily, while continuing to exert sufficient sealing pressure to the parts. This results because the relatively large flange portions 12 and 14 impart effective sealing forces to the parts and, in addition, a force sufficient to return the hinge portion 16 to its original shape. In this manner, the seal deflects readily to provide the necessary following or tracking movement. It should be apparent that the seal 10 is capable of substantial deflection, while at the same time, it maintains effective sealing pressures at the surface to be sealed.

WHAT WE CLAIM IS:—

1. A metal seal, comprising a continuous, one-piece, annular, generally C, V or U-section body of resilient metal having a pair of radially-directed flange portions joined by an integral hinge portion, the ratio of the thickness of the hinge portion to that of any part of the flange portions being such that when the flange portions are loaded axially of the annular body toward one another, the elastic limit of the hinge portion is less than that of any part of the flange portions.

2. A metal seal according to Claim 1, wherein the ratio is less than one and the metal is stiff resilient metal.

3. A metal seal according to either of Claims 1 and 2, wherein the thicknesses of the flange portions are substantially the same.

4. A metal seal according to Claim 3, wherein the ratio of the thickness of the hinge portion to that of each of the flange portions is about 1 to 8.

5. A metal seal according to any of Claims 1 to 4, wherein the hinge portion is arranged to couple the flange portions along the inner diameter of the annular body.

6. A metal seal according to any of Claims 1 to 4, wherein the hinge portion is arranged to couple the flange portions along the outer diameter of the annular body.

7. A control valve fitted with a metal seal according to Claim 1.

8. A control valve and metal seal, combination, comprising a valve body including inlet and outlet ports, a valve cage member having a coefficient of expansion differing from that of the valve body positioned within the valve body between the inlet and outlet ports, the valve cage member being secured to the valve body in such a manner to define a seal cavity between the cage member and the valve body, the cage member defining a valve seat, a valve plug mounted within the valve cage member for reciprocal movement toward and away from the valve seat, a metal seal comprising a continuous, one-piece, annular, generally C, V or U-section body of resilient metal secured within the seal cavity, the metal seal having a pair of radially-directed flange portions coupled together by an integral hinge portion, the ratio of the thickness of the hinge portion to that of any part of the flange portions being such that when the flange portions are loaded axially of the annular body toward one another, the elastic limit of the hinge portion is less than that of any part of the flange portions, whereby the metal seal exhibits sufficient resilient deflection and load-carrying characteristics to maintain a leak-tight seal notwithstanding thermal contractions or expansions of the seal cavity.

9. A metal seal according to Claim 1 substantially as hereinbefore described with reference to any of Figures 2 to 6 of the accompanying Drawings.

10. A control valve according to Claim 7 substantially as hereinbefore described with reference to Figures 7 and 8 of the accompanying Drawings.

11. A control valve fitted with a metal seal according to any of Claims 2 to 6 and 9.

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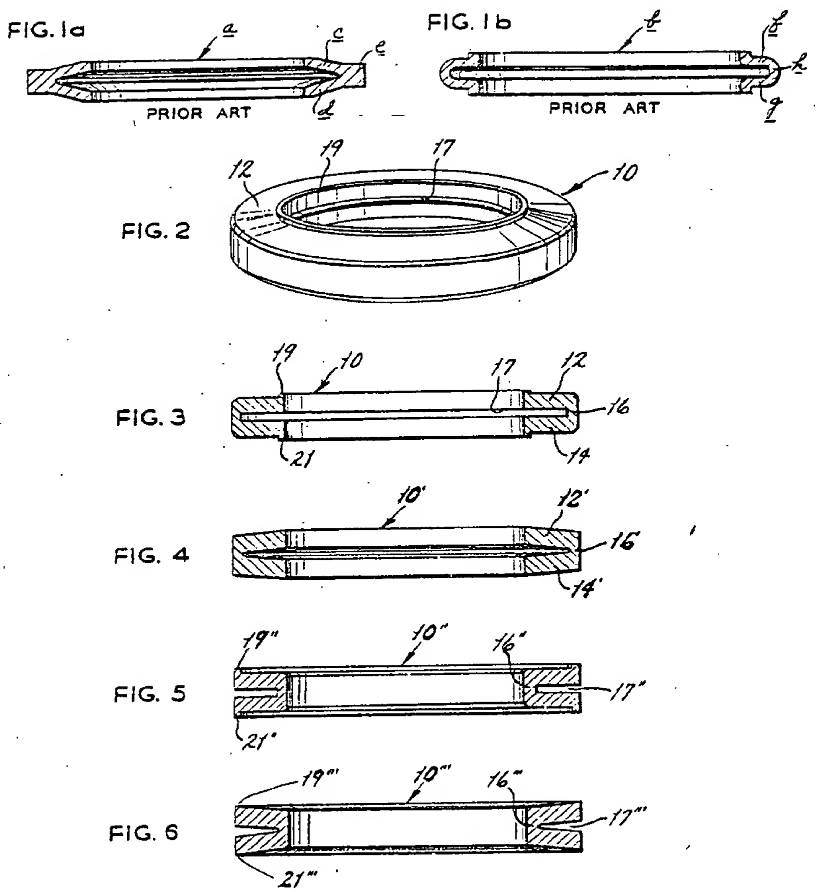
1368773 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1



1368773 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 7

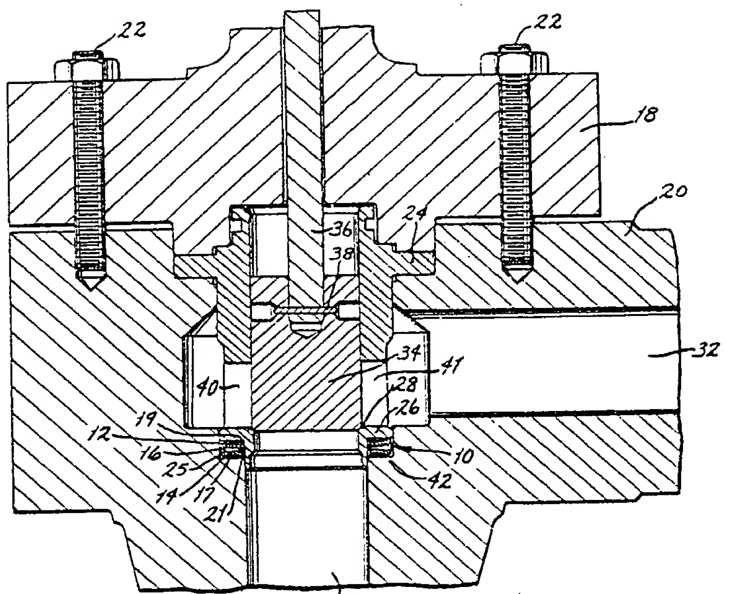


FIG. 8

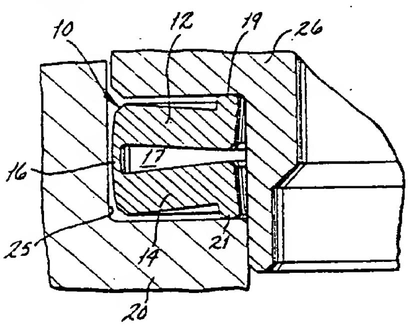
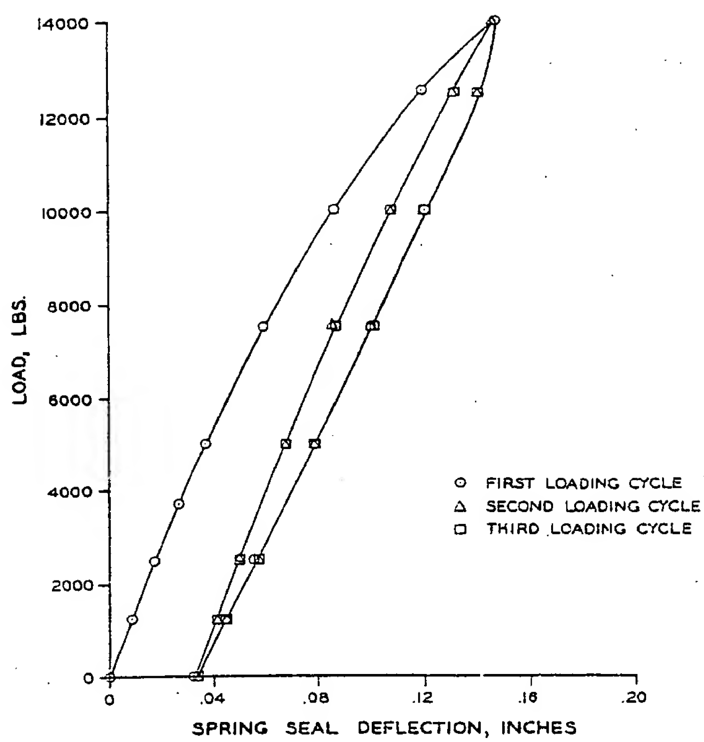


FIG. 9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SPRING SEAL DEFLECTION, INCHES
FIRST LOADING CYCLE
SECOND LOADING CYCLE
THIRD LOADING CYCLE